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Transport Cost Elasticities:
A Cross-National European Comparison

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Research Memorandum 1997-71

December 1997



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Elasticities: A Cross-National European Comparison

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**A META-APPROACH TO INVESTIGATE THE VARIANCE IN TRANSPORT
COST ELASTICITIES:
A CROSS-NATIONAL EUROPEAN COMPARISON**

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Abstract

Results from past studies on transport elasticities show a large variance. The aim of this paper is to assess key factors that influence the sensitivity of travellers to transport costs in Europe, by carrying out a comparative analysis of the different elasticity values of demand for transport that are being used in some of the different Member States.

Our empirical base are elasticity studies in four different European countries, namely Norway, Finland, The Netherlands and the UK. We are dealing here with a data set consisting of a limited number of observations (i.e. elasticity study results), thus we are facing a high level of uncertainty. Therefore, our in-depth analysis of these causes is based on a meta-analytic approach. Such an approach can be used to extract lessons from a limited set of different research studies. The specific meta-analytic method used is called rough set analysis.

The paper starts with a description of the concept of transport price elasticity. It succeeds with a review of the literature. Then an in-depth analysis of possible causes of variances between elasticity values across the four European countries is presented based on rough set analysis.

It appears that the emerging importance from the literature of the difference between aggregate, empirical-based research methods and the use of disaggregate choice models, as well as model assumptions, for explaining the variance in elasticity values across studies are largely supported by our rough set analysis. From this analytical approach it also appears that the country involved, the number of competitive modes and type of data collected have a relative strong explanatory power for the size of elasticities.

Keywords: transport policy, price elasticity, comparative analysis, **meta-analysis**

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1 Introduction

Public authorities in many countries have an increasing interest in the financial side of the transport system. Various agencies involved with the provision of transport infrastructure are faced with a mismatch between supply and demand. On the one hand, we observe endless traffic jams on main arteries and in urban areas, but on the other hand we also witness empty motorways in more peripheral areas. It is increasingly recognized that the private mechanism is not properly used to ensure a balance between supply and demand. However, the sheer introduction of market principles in transport policy does not mean an automatic panacea for all frictions in the transport systems under all circumstances, as we have different types of travellers, different (competing and complementary) modes, different travel motives, different goods, different time horizons, different distances to be bridged, and different (site-specific) travel conditions. So we need to have more insight into behavioural responses.

The standard instrument 'par excellence' advocated by economists, is the price elasticity of demand. This instrument has traditionally often been used by public transport operators to assess the behavioural implications of a change in the fare system. But it has also often been used by fiscal authorities to estimate the financial revenue consequences of a rise of gasoline taxes in the private transport sector. Furthermore, it has also been used to make an assessment of the sensitivity of car drivers in case of a toll system (bridges, tunnels, toll roads). And more recently, the notion of the price elasticity has gained much popularity in the context of road pricing proposals in many countries, through which not only the private but also the social costs of surface transport might be incorporated in the travellers' decisions.

In the past years, several studies in European countries have been undertaken to assess price elasticities of demand in the transport sector. There is a great diversity of empirical results, which do not show an overwhelming similarity. Clearly, most investigations have been made on a non-controlled basis, so that the comparability of the results of these studies is rather feeble. But nevertheless, it makes sense to analyse the differences in statistical results more carefully, in order to identify common backgrounds and site-specific differences more precisely. This would also allow for more transferability of results under given conditions.

In this context, meta-analysis may play an important role. Meta-analysis has been developed as a tool for comparing and synthesizing results from different studies with a similar goal in the natural sciences, and has increasingly found its position in the social sciences (e.g., experimental psychology and economics). We refer for more details to Van den Bergh et al. (1997). This methodological tool seems to offer interesting opportunities for comparing different findings and will hence also be used for a comparative statistical exercise on cost elasticities in the transport sector in different European countries.

The aim of this paper is to assess key factors that influence the sensitivity of travellers to transport costs in Europe, by carrying out a comparative analysis of the different elasticity values of demand for transport that are being used in some of the

different Member States¹. This comparative analysis is based on a meta-approach and the specific meta-analytic method used is called rough set analysis.

The paper is organized as follows. Section 2 elaborates on the concept of transport price elasticity. Section 3 covers an initial review of the literature. This literature investigation is carried out because we need to know till what extent there is available knowledge on elasticity values for European countries. Section 4 presents an in-depth analysis of possible causes of variances between elasticity values across four European countries (Norway, Finland, The Netherlands and the UK). Section 5 contains the conclusions.

2 The Concept of Price Elasticity

A demand price elasticity expresses the change in demand induced by a change in price. More precisely an elasticity is defined as:

$$\frac{\text{Relative change in demand}}{\text{Relative change in price}}$$

Denoting the quantity demanded by Q and the price by P , demanded quantity can be expressed by a function $Q=f(P)$. The elasticity is then defined by:

$$\frac{dQ}{dP} \cdot \frac{P}{Q}$$

This elasticity defined by the derivative and values for a point on the function is called a *point* elasticity. Normally an elasticity will be estimated by the change in demand induced by a finite change in price, i.e., by:

$$\frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} = \frac{Q_2 - Q_1}{P_2 - P_1} \cdot \frac{P}{Q}$$

where Q is the mean of Q_1 and Q_2 , and likewise for P . This is an *arc* elasticity.

Point and arc elasticity values for travel demand can be defined in the same way. Q is then the quantity of travel and can for instance be defined as kilometres travelled or as the number of trips.

Instead of a demand for travel in general, demand for specific modes of travel such as bus, car or rail may be studied. Mode specific demand leads to mode-specific elasticity values. The elasticity of one mode of transport with respect to (wrt) its own price is called *own-price* elasticity. The elasticity of one mode of

¹ The data used for this empirical application have been obtained from the EXTRA research project in the Transport Programme of the European Commission.

transport wrt the price of another is called the *cross-price* elasticity. Since a price increase for a mode of transport will tend to reduce the demand for this mode of transport the own-price elasticity values are negative. The cross-price elasticity values are normally positive, an increase in the price of one mode of transport will transfer some of the demand to the other modes.

Unfortunately, this seemingly simple concept of elasticity is deceptive. The reaction to a price change is not context-free, it depends on the situation. Different kinds of elasticities are therefore defined.

Of theoretical interest is the difference between Marshallian or ordinary and Hicksian or compensated elasticities. In the first case no compensation is given for a price rise, In the case of compensated elasticities compensation is given so that the utility level is constant. No *direct* compensation is usually given in real life though in cases of tax increases indirect compensation can take place in the shape of better roads, etc. The cited elasticities can therefore be regarded as ordinary.

For mode-specific elasticities it is important to distinguish between mode-choice and regular demand elasticities. Mode-choice elasticities express the change in demand for one mode given a fixed demand of traffic for all modes. They do not take into account the change in price on the aggregate volume of traffic. Mode-choice elasticities are therefore a lower limit to regular demand elasticities.

Of equal importance is the distinction between short-run and long-run elasticities. In the long run there are more possibilities to adjust to changed prices than in the short run. Long run demand functions tend therefore to be more elastic than short-run demand functions. The elasticity values are larger (in absolute term).

The purpose of travel will have an influence on elasticities. Travel to work is normally less elastic than travel for leisure purposes, since the latter can be cancelled more easily. Elasticities for rush-hour travel (peak) must therefore be distinguished from off-peak elasticities.

These examples ought to make it clear that elasticities estimated with different methods under different circumstances are not necessarily comparable.

3 Existing Elasticity Reviews

In the past an enormous number of studies have been carried out that aimed to assess values of transport elasticities. Numerous methods have been used in these studies. The European Commission (1996) provides a list of the different sources where elasticity values can be found, or the different methodologies for the estimation of elasticity values. The following is a summary of these methodologies.

- *Before and after surveys*: Elasticities are calculated by measuring demand before and after a price change.
- *Aggregate time series analysis*: Econometric models based on monthly, quarterly or annual data.
- *Aggregate cross sectional data*: Data collected over one time period.
- *Aggregate time series and cross sectional analysis*: Pooled time series and cross sectional data
- *Disaggregate cross sectional analysis*: Data collected from small economic units,

typically household or individuals.

- *Hypothetical market research*: Elasticities are inferred from peoples expressed behaviour.
- *Model-based elasticities*: Elasticities derived from running computer models of travel behaviour and the change in travel from changes in price.

Extensive literature reviews have been undertaken by Goodwin (1988, 1992) and Oum et al. (1990, 1992). Between them they probably cover most of the work up till the time of their reviews. Two other important literature reviews are a report commissioned by the Department of Transport in Britain (Halcrow Fox, 1993) and a report of the European Commission (European Commission, 1996).

In these historical reviews, for practical reasons elasticities have been grouped in the summary results without always discussing the different ways the elasticities have been estimated, although the authors of the reviews cited here are of course aware of these problems. E.g., Goodwin (1988, 1992) lumps various estimates of the same mode to calculate a total mean. As he says himself he does that fairly uncritically, taking all results by equal merit, apart from a few studies that were omitted due to incomprehensibility or absurdity. He then subdivides the elasticities according to data type and length of period. Oum et al. (1990, 1992) do not calculate means of elasticities but list the whole range of estimates. In their World Bank working paper they present subjective "most likely" ranges of elasticity values of demand for various travel modes.

Across the studies, the diversity in modes included, type of data and methods of estimation is large. This counts also for the geographical diversity that is equally large. In view of the discussion in Oum et al., the estimated elasticities are not directly comparable. Even though mode choice elasticities may be distinguished from market demand elasticities, the various mode choice elasticities may not be comparable due to the inclusion of different alternative modes. Besides, bus as an alternative to car may be different according to frequency, comfort and speed. Estimated mode choice elasticities would then differ.

Therefore, generalising the value of an estimated elasticity to different circumstances is a dubious practice. The same can be said about calculating the mean of elasticities from different studies.

On the other hand, when numerous studies are carried out with different data and models give similar values for an elasticity the result may be regarded as robust. The conclusion of Oum et al. (1992) that the demand for car usage and urban transit are unambiguously inelastic is therefore strongly supported. If, however, the choice of policy in a particular situation is dependent on precise estimates of elasticities, estimation of elasticities should be undertaken for this particular situation.

Oum et al. (1992) identify a number of issues which can cause different elasticity estimates, that they believe warrants attention. The most important of these are the presence of intermodal competition, the use of different functional forms and different locations. It is concluded that 'While some generalisations, particularly on demand elasticities of car usage and public transit are possible, across-the-board generalisations about transport demand elasticities are impossible'.

Most of the elasticities in these reviews are derived from empirical studies. An

alternative way of estimating elasticities is by using disaggregate travel demand models, which is the case for some of the surveys in the applied meta-analysis presented in the sequel of this paper. Such models can produce estimate of elasticities for not only mode specific elasticities for different purposes but also for different segments of the population. However, it should be noted that values from travel demand models are often very different from those from empirical studies.

Halcrow Fox (1993) concludes those literature values, i.e., based on empirical studies, are 50% to 200% higher than model elasticities. The main reason for this is that the results from models depend on a limited number of variables and thus do not allow for all the many causes of variation that exists in reality. Empirical values, however, are more likely to include the system effects, within a specific time scale. This leads Halcrow Fox to conclude that model elasticities should be treated as minimum values.

4 Meta-analysis of Transport Elasticities

4.1 Introduction

We have seen in the previous sections that results from past studies on transport elasticities show a large variance. In this section we explore the factors that cause these differences. Knowledge on these factors may be useful for harmonisation of (future) international research on the sensitivity of transport demand to prices.

Our empirical base are elasticity studies in four different European countries, namely Norway, Finland, The Netherlands and the UK. We are dealing here with a data set consisting of a limited number of observations (i.e. elasticity study results), thus we are facing a high level of uncertainty. Therefore, our in-depth analysis of these causes is based on a meta-analytic approach. Such an approach can be used to extract lessons from a limited set of different research studies.

Meta-analysis is originally a statistical procedure for combining and comparing research findings from different studies focusing on similar phenomena (see Hedges and Olkin 1985, Light and Pillemer 1984, and Wolf 1986). Meta-analysis is particularly suitable in cases where research outcomes are to be judged or compared (or even transferred to other situations), when there are no controlled conditions. In the past decade, a variety of meta-analytical methods has been developed (see e.g., Hunter et al. 1982, and Rosenthal 1991). Most meta-analytical techniques are designed for sufficiently large numbers of case studies, so that statistical probability statements can be inferred. And in this respect, meta-analysis has clearly demonstrated its validity and usefulness as a methodological tool for comparative study in the social sciences.

In conclusion, meta-analysis is largely a mode of thinking and may comprise a multiplicity of different methods and techniques, which are often statistical in nature. Especially in case of quasi-controlled or non-controlled comparative experimentation, the level of information is often not cardinal, but imprecise (e.g., categorical, qualitative, fuzzy). In recent years, rough set theory has emerged as a powerful analytical tool for dealing with 'soft' data. Rough set theory aims to offer a

classification of data measured on any information level by manipulating data in such a way that a range of consistent and feasible cause-effect relationships can be identified, while it is also able to eliminate redundant information. Therefore, we will give a concise introduction to rough set theory (see also Pawlak 1991, Slowinski and Stefanowski 1994, and Greco et al. 1995).

Rough set analysis is a non-parametric statistical method that is able to handle a rather diverse and less immediately tangible set of factors. Rough set analysis, proposed in the early 1980's by Pawlak (1982, 1991), provides a formal tool for transforming a data set, such as a collection of past examples or a record of experience, into structured knowledge, in the sense of ability to classify objects in distinct classes of attributes. In such an approach it is not always possible to distinguish objects on the basis of given information (descriptors) about them. This imperfect information causes indiscernibility of objects through the values of the attributes describing them and prevents them from being unambiguously assigned to a given single set. In this case the only sets which can be precisely characterized in terms of values or ranges of such attributes are lower and upper approximations of the set of objects. Rough set theory has proven to be a useful tool for a large class of qualitative or fuzzy multi-attribute decision problems. It can effectively deal with problems of explanation and prescription of a decision situation where knowledge is imperfect. It is helpful in evaluating the importance of particular attributes and eliminating redundant ones from a decision table, and it may generate sorting and choice rules using only the remaining attributes.

4.2 Potential causes of variance between elasticities in different regions

In this section, we will focus on the fact that choices regarding different aspects of research on transport demand elasticities may have impacts on the size estimations of the elasticities. From the theory we can derive criteria which can be used to evaluate the results of different elasticity studies. Such a checklist of criteria can be used to evaluate the differences between similar elasticities by means of meta-analysis.

Nature (definition) of the elasticity

This criterion relates to the type of elasticity measured. It is marked that often different types of elasticity are compared with each other, without noticing that they differ in nature. Various types of transport elasticities exist. The most important distinctions are regular versus mode-choice elasticities, own-price versus cross-price elasticities, and point versus bow elasticities. In this report we restrict ourselves to regular, own-price elasticities. Important aspects of the nature of the elasticity are:

■ *The choices under consideration.* A distinction must be made between number of trips, distance travelled, modal choice, route choice etc.

■ *The independent variable.* In principle, three explaining variables can be used on the basis of which elasticities can be calculated: price, travel time and income. These variables show a high level of heterogeneity (e.g. perceived travel time in a bus is different from waiting at a bus stop; the issue of generalised costs).

■ *The specific market segment.* The transport demand market can be segmented to

different population classes with different sensitivities to policy measures. Also a distinction can be made between travel motives.

Size of choice possibilities

In general, the level to which substitution is possible is the main criterion that determines the size of a given type of elasticity. Substitution can be defined as a change in choice behaviour (e.g. modal choice and route choice) in order to hold as much as possible the existing activity pattern. If substitution is possible, it may be expected that resulting elasticities are high. Important aspects are:

■ *Level of aggregation over alternatives.* The level of aggregation over alternatives is important for the evaluation of the size of the elasticities. The higher the level of aggregation, the less the number of substitutes. This will lead to lower elasticities. In addition, aggregation will lead to averaging out the underlying variation in the elasticities, as no allowance is made for the heterogeneity of the alternatives to be chosen. E.g. a fuel price elasticity of car use will lie in between the price elasticity of diesel and that of (super) petrol. For an effective differentiated price policy, it is necessary to have insight into the underlying elasticities.

■ *Time horizon.* The possibilities to react to changing transport conditions will in general be larger in the longer run than in the shorter run, as in the longer run also changes in location choice and asset holding resulting from changing transport conditions may take place. Therefore, long term elasticities are expected to be higher than short term elasticities.

■ *Travel distance.* It is plausible that there are differences in the sensitivities to price change between shorter distance trips and longer distance trips. Therefore the geographical coverage of mobility surveys is an important factor.

■ *Choice possibilities.* An important reason for the existence of low elasticity values in various studies is that many people do not have a choice possibility. This implicates that the share of choice travellers in the sample investigated co-determines the size of the elasticities.

■ *Other factors.* From elasticity theory we may derive several other factors that have an influence on the estimated size of elasticities. For example, there is the thesis that choice travellers often have incomplete information on the real costs and travel times. These uncertainties implicate that people not only react on the basis of true travel costs and travel times, but on the basis of expected travel costs and travel times, and of the associated risk that their expectation is wrong.

Model specification

Also from the type of research methodology we may derive criteria for the evaluation of elasticities. The important ones are:

■ *Aggregate and disaggregate models.* The most important criterion is likely to be whether the model used is an aggregate or a disaggregate model. Aggregate models do not make an allowance for the fact that individuals make choices based on individual-specific circumstances. Therefore problems related to methods of aggregation may cause significant biases in the elasticities. In most cases this will lead to lower elasticities resulting from aggregate models in comparison with disaggregate models. In addition, aggregate models do not make an allowance for

the large variation in individual mobility behaviour, even within groups with similar characteristics. In other words, the use of aggregate models is based on a low level of variation in (aggregate) behaviour, which causes a less precise estimation of model parameters.

■ *Number of competitive modes taken up in the model.* In addition to real-world choice possibilities does also the number of modes taken up in (choice) models have an influence on the elasticity values. Of course this is a matter of proper modelling, but usually there are discrepancies between real-world choice possibilities and model possibilities.

■ *Control for other factors.* In certain cases two situations are being compared from which is concluded that a policy measure has led to a certain change in mobility behaviour. However, also other (external) developments may have had an impact on the dependent variables. It is therefore important that for the models used in the different studies there has been a check on such developments.

■ *The functional form of the model.* The functional form of the model used has in a number of respects an influence on the size of elasticities. Different model types may generate different elasticity types. A model which is based on explicit economic theory allows for a distinction between generation and substitution effects (gross and net substitution). Some models yield higher elasticities when changes in the independent variables, like transport price, are higher. Dynamic models allow for an explicit modelling of short term and long term effects.

Criteria derived from the data

■ *Type of data source.* There exist various data types: cross-section, time series, panel and stated preference data. The use of these data has different consequences for the size of the estimated elasticities. For example, it appears that elasticities based on cross-section data are higher than elasticities based on time series data. Also it appears that elasticities based on stated preference data are higher than cross-section data, unless they are re-scaled. Therefore a proper recording of the data source from which elasticities are calculated is of large importance. In addition, other aspects related to the data source are important:

■ *The operationalisation of the variables.* Even slight differences in variable definitions of income, transport price and travel times (e.g. monetary or generalized travel costs) may cause significant differences in the estimated elasticities.

■ *General problems with the data source.* If there are general problems related with the data source, this should be properly recorded. For instance, results from panel data may be influenced by selectivity in panel attrition.

■ *Year of collection of the data.* In general the sensitivity to price change is likely to change over time, especially when large time periods between measurements are concerned (more than 10 years). In the past decades the role of transport has rapidly increased in the whole society.

Quality of research

In addition to the used theory, the model specification and the data used it is important that the research from which elasticities are derived meets some quality standards. We may take into consideration here:

■ *Used statistical techniques.* This regards the issue whether on the basis of statistic theory may be expected that consistent estimators are used for the determination of parameter values, and whether chosen techniques are correctly applied.

■ *Sample size.* The size of the sample determines the level of representativeness of the results of the study for the population investigated.

From the considerations set out systematically above, we may formulate a list of items on the basis of which we will apply a meta-analysis. The aim is to assess the most important aspects that are responsible for the variation of elasticity estimates between the different studies in the countries investigated.

4.3 Application of rough set analysis

As mentioned in Section 4.1, rough set theory is essentially a classification method, devised for non-stochastic information. This also means that ordinal or categorical information (including dummies) may be taken into consideration. This makes rough set analysis particularly useful as a meta-analytical tool in case of incomplete, imprecise or fuzzy information. We can expect the following results from the rough set analysis:

- (a) evaluation of a relevance of particular condition attributes;
- (b) construction of a minimal subset of variables ensuring the same quality of description as the whole set, i.e. reducts of the set of attributes;
- (c) intersection of those reducts giving a core of attributes that cannot be eliminated without disturbing the quality of description of the set of attributes;
- (d) eliminating of irrelevant attributes.

The application of rough set analysis on transport elasticity values in different countries proceeds in two successive steps, namely the construction of an information survey and the classification of information contained in this survey.

Information survey

In our case an information survey is constituted by a series of public transport elasticity studies in the four European countries. Included are both aggregate and disaggregate elasticity studies. The information survey contains characteristics (attributes) of these studies. It is impossible to collect information for all of the criteria listed in the previous section. Therefore we have chosen to make a selection out of these. The information survey is reflected in Table 1.

Table 1. Concise survey table for meta-analysis of transport elasticities for public transport in four European countries.

1 <i>Case</i>	2 <i>Country</i>	3 <i>Year of data collection</i>	4 <i>Level of aggregation</i>	5 <i>Indicator of transport demand</i>	6 <i>Geographical coverage</i>	7 <i>Number of competitive modes</i>	8 <i>Data type</i>	<i>Model type</i>	<i>Elasticity value</i>
1 Helsinki, 1988	Finland	1988	bus, tram, metro, train	trips	urban	2	cross-section	nested logit	-0.48
2 Helsinki, 1995	Finland	1995	bus, tram, metro, train	trips	urban	3	cross section	logit	-0.56
3 Sullström, 1995	Finland	1966-90	all	person km	urban, interurban	1	repeated cross section	linear demand OLS	-0.75
4 Dutch Mobility Panel	Netherlands	1984-85	bus, tram, metro	trips	urban, semi-urban	2	panel	linear demand OLS	-0.35/-0.40
5 BGC, 1988	Netherlands	1980-86	bus, tram, metro	trips	urban, semi-urban	2	time series	linear demand OLS	-0.35/-0.40
6 Roodenburg, 1983	Netherlands	1950-80	bus, tram, metro	person km	urban, semi-urban	1	time series	linear demand OLS	-0.51
7 Fase, 1986	Netherlands	1965-81	bus, tram, metro	person km	urban	1	time series	linear demand OLS	-0.53/-0.80
8 Gunn, 1987	Netherlands	1986	train	person km	semi-urban	2	cross-section	discrete choice	-0.77
9 Oum, 1992	Netherlands	1977-91	bus, tram, metro	person km	urban, semi-urban	2	time series	translog utility function	-0.74
10 Oslo	Norway	1990-91	all	trips	urban	3	cross-section	multinomial logit	-0.40
11 Norway, long distance	Norway	1991-92	bus	trips	interurban	5	cross-section	multinomial logit	-0.63
12 UK, national	UK	1991	all	trips	urban, interurban	4	cross-section	nested logit	-0.15

Classification of information

The observations or objects are classified into various categories for each attribute separately. This applies to both categorical and ratio information. In general, some sensitivity analysis on the classification used is meaningful, as a balance has to be found between homogeneity and class size. This classification exercise leads then to a decision table, in which all objects are subdivided into distinct classes for each relevant attribute. The classes used are reflected in Table 2. The resulting coded information table is reflected in Table 3. (N.B. when we speak of high respectively low values of the elasticity size, we refer to the *absolute* value of the elasticity).

Table 2. Categorisation of variables investigated.

Elasticity value	4	Indicator of transport demand (IND)
1 lower than -0.40		
2 -0.40 to -0.50	1	Number of trips
3 -0.50 to -0.60	2	Number of person km
4 higher than -0.60		
Explanatory variables:	5	Geographical coverage (GEO)
	1	Urban
	2	Urban and semi-or interurban
	3	Interurban
1 Country (COU)	6	Number of competitive modes (CMD)
1 Finland	1	One
2 Norway	2	Two
3 Netherlands	3	Three
4 UK	4	Four and more
2 Year of data collection (YEA)	7	Data type (DAT)
1 1985 and before (including studies using data periods over 10 years of which the medium year was before 1986)	1	Time series
2 1986 and after (including studies using data periods over 10 years of which the medium year was after 1986)	2	Survey, cross-section
	3	Survey, panel
3 Level of aggregation (AGG)	8	Model/estimation type (MOD)
1 Bus, tram, metro, train	1	Basic OLS (linear demand models)
2 Bus, tram, metro	2	Discrete choice (probit/logit)
3 Bus	3	Other types
4 Train		

Table 3. Coded table for meta-analysis of transport elasticities for public transport.

<i>Case/attribute</i>	COU	YEA	AGG	IND	GEO	CMD	DAT	MOD	Elasticity value
1	1	2	1	1	1	2	2	2	2
2	1	2	1	1	1	3	2	2	3
3	1	1	1	2	2	1	2	1	4
4	3	1	2	1	2	2	3	1	2
5	3	1	2	1	2	2	1	1	2
6	3	1	2	2	2	1	1	1	3
7	3	1	2	2	1	1	1	1	3
8	3	2	4	2	2	2	2	2	4
9	3	1	2	2	2	2	1	3	4
10	2	2	1	1	1	3	2	2	2
11	2	2	3	1	3	4	2	2	3
12	4	2	1	1	2	4	2	2	1

Applying this classification to the samples of elasticity studies within the four investigated European countries, four main sets of indicators and outputs can be calculated.

(1) The *reducts*, i.e. all combinations of explanatory or independent variables which can completely determine (or explain) the variation in the dependent variable, without needing other explanatory variables. The reducts are given in Table 4. There appear to be, on the basis of the chosen set of characteristics and classification of these characteristics, two competitive theories for explaining the variance in the estimated elasticity values. The first is that this variance is completely determined by the combination of the country where the data are collected, the number of competitive modes, the type of data collected and the type of model used. The second theory is that this variance is completely determined by the country, the indicator for transport demand, the number of competitive modes and the type of data collected.

(2) The *core*, i.e. the set of variables that are in all reducts as discussed under (1), or that are part of all theories. The core appears to consist of the variables country, number of competitive modes and type of data collected. Without these characteristics, it is impossible to classify the results of the elasticity studies according to the considered classification. This means that these three variables have the strongest explanatory power for the elasticity size. In conclusion, in addition to the practical findings mentioned earlier in this chapter on the difference between empirical-based research methods and the use of disaggregate choice models, also country differences have a major influence on the elasticity value.

Table 4. Reducts and core.

Reducts	Set no.1 {COU, CMD, DAT, MOD} Set no.2 {COU, IND, CMD, DAT}
Core	{COU, CMD, DAT}

(3) The *lower and upper approximation*, and derived accuracy of relationships for each value class of the decisional variable. The latter is the lower divided by the upper approximation of each class. From this can also be derived an accuracy and quality of classification (i.e. choice of thresholds). The results are shown in Table 5. For all classes of the elasticity value the accuracy is 1 (which is the maximum value). Also the accuracy and quality of classification is equal to 1, the highest possible value. This means that on the basis of the chosen characteristics the studies in our sample are fully discernible to the four classes of the elasticity value. This strengthens the conclusions on the other indicators from the rough set analysis.

Table 5. Accuracy and quality of the classification of the elasticity value.

Elasticity value class	Accuracy	Lower approximation	Upper approximation
lower than -0.40	1	1	1
-0.40 to -0.50	1	4	4
-0.50 to -0.60	1	4	4
higher than -0.60	1	3	3
Accuracy of classification: 1; Quality of classification: 1			

Note: the accuracy for each class is the lower divided by the upper approximation.

(4) *Rules*, i.e. exact or approximate relationships between explanatory variables and dependent variables. These may be considered as 'if ... then ...' statements. A rule may be exact (or deterministic), or approximate (or non-deterministic). An exact rule r_{ij} guarantees that the values of the decision attributes correspond univocally to the same values of the condition attributes (same conditions, same decisions); an approximate rule, on the other hand, states that more than one value of the decision attributes correspond to the same values of the condition attributes (same conditions, different decisions). Therefore, only in the case of exact rules, using the information contained in the decision table it is always possible to state with certainty if an object belongs or not to a certain class of the decision variable. An exact rule therefore offers a sufficient condition of belonging to a decision class; an approximate rule (only) admits the possibility of this.

Table 6 provides information on this. The support of rules by cases is also a useful indicator. If a rule is supported by more objects, then it is more important, for instance, in summarizing the different single study results.

Table 6. Rules generated by the rough set analysis.

Classes of dependent attributes	Implied class of elasticity size
COU=UK	lower than -0.40
COU=Finland, IND=trips, CMD=2	-0.40 to -0.50
COU=Norway, IND=trips, CMD=3	-0.40 to -0.50
COU=Netherlands, IND=trips, CMD=2, DAT=panel	-0.40 to -0.50
AGG=bus	-0.50 to -0.60
AGG=bus/tram/metro, CMD=1	-0.50 to -0.60
COU=Finland, AGG=bus/tram/metro/train, CMD=3	-0.50 to -0.60
COU=Netherlands, AGG=bus/tram/metro, IND=trips, CMD=2, DAT=time series	-0.50 to -0.60
IND=person km, GEO=urban and interurban	higher than -0.60

We see from the decision algorithm in Table 6 that all rules generated on the elasticity study information survey, using the classes of Table 3, are deterministic. Some statements may then be derived on the influence of the variables occurring in this algorithm, but we should take into mind that some of these rules are supported by only one observation, e.g. the case of where the country UK implies a relatively low elasticity value. Nevertheless, within the limits of our small data set we may derive some interesting information from these rules. A rule supported by more observations is that when the area covered is a mixture of the urban and the inter-urban level, the elasticity value is relatively high.

4.4 Conclusions from the meta-analysis

The conclusions from the literature reviews on the importance of the difference between aggregate, empirical-based research methods and the use of disaggregate choice models, as well as the model assumptions, seem to be largely supported by our in-depth analysis of a larger set of potential influencing factors by means of a meta-analysis. In this analysis, there appear to be, on the basis of a chosen classification of study characteristics, two competitive theories for explaining the variance in the estimated elasticity values. The first is that this variance is completely determined by the combination of the country where the data are collected, the number of competitive modes, the type of data collected and the type of model used. The second theory is that this variance is completely determined by the country, the indicator for transport demand, the number of competitive modes and the type of data collected. Thus it appears that the variables country, number of competitive modes and type of data collected have the strongest explanatory power for the elasticity size. The result of the meta-analysis is thus that in addition to the practical findings on the difference between empirical-based research methods and the use of disaggregate choice models, also country differences have a major influence on the elasticity value. *This means that, even when the estimation method is the same in terms of used data and the model specification, the elasticities for the different European countries should be looked at very carefully.* The situations

between the countries may differ to a large extent. For example, in the Netherlands is the use of the bicycle a relative important mode in comparison with the other countries. This is favoured because of the relatively small travel distances in the Netherlands, the flat surface and the good infrastructure provided for the bicycle. The public transport elasticity of those who are quite dependent on public transport (e.g. the young people) is therefore quite high in comparison with other countries. The relatively small travel distances in the Netherlands (looking at both urban and interurban trips), also enlarges substitution possibilities between other modes.

Further reasons for the high impact of the country on elasticity values can be found in the cultural differences between the various countries, but also in differences on the infrastructural side and the quality of public transport as these determine the level of competitiveness between the transport modes.

5 Conclusions

The goal of this paper was to assess the factors that influence the elasticities of travellers to transport costs in Europe, by carrying out a comparative analysis of the different elasticity values of demand for transport. From an investigation of existing literature, it was concluded that past research on transport elasticities has mainly been based on an empirical base, focusing on aggregate elasticities. Such elasticities appeared to be generally higher than model elasticities. The main reason for this is that the results from models depend on a limited number of variables and thus do not allow for all the many causes of variation that exists in reality. Empirical values, however, are more likely to include the system effects, within a specific time scale.

The results of disaggregate travel demand models depend highly on the implicit and explicit assumptions in the model (model structure, selected variables and quality of calibration). This problem is even larger in the case of disaggregate models (estimating disaggregate elasticities) than in the case of aggregate models (estimating aggregate elasticities).

The above conclusions on the importance of the difference between aggregate, empirical-based research methods and the use of disaggregate choice models, as well as the model assumptions, seem to be largely supported by our in-depth analysis of a larger set of potential influencing factors by means of a meta-analysis. From this analytical approach it appears that the variables country, number of competitive modes and type of data collected have the strongest explanatory power for the elasticity size. The result of the meta-analysis is that in addition to the practical findings on the difference between empirical-based research methods and the use of disaggregate choice models, also country-specific factors play a large role. This means that, even when the estimation method is the same in terms of used data and the model specification, the elasticities for the different European countries should be looked at very carefully. Relevant characteristics of the specific situation of one country are amongst others the fact that certain modes may be favoured by natural circumstances and travel distances (e.g. the bicycle in the Netherlands). But also cultural differences and differences in the quality of public transport are important, as these also determine the level of competitiveness between the transport modes.

The findings above on the importance of country-specific factors that determine the price sensitivity of travellers implies that the formulation of a common transport price policy at the European level, in terms of harmonizing prices, is a rather difficult task, and will probably not lead to a first-best solution to the rising negative transport externalities in Europe. Instead, pricing policies for public transport should be adapted to local situations in order to be able to derive optimal effects.

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